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The Role of Structural Elements in Reconnaissance of Karst Hydrology in the Lar Catchment's, Iran

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Abstract: Information on karst hydrology is needed to develop water quality and quantity management strategies. Karst aquifers are characterized by high heterogeneity and spatial variability of hydrological parameters. one possible approach to study them is investigation of relation ship between geostructural element and hydrological elements. In this study various types of assessments have been carried out including analysis of karst related features from aerial photo, satellite image, geological map and fieldwork. Water quality and quantity characteristics were investigated with respect to catchment characteristics and integrated in GIS. Hydrograph analysis was done to estimate ground water contribution to stream flow. The regression results indicated that occurrence of karst water resources were highly correlated to geological structural elements. Demonstrated was the importance of structural geological elements, such as lineaments and faults, in reconnaissance of karst hydrology.

Key words: Karst · Reconnaissance · Structural element · Hydrology · Lar

INTRODUCTION

Detailed knowledge of hydrological and structural elements in karstic area is of utmost importance in order to understand interaction between structural and hydrological elements. Fracture distributions involving orientation, continuities, densities, intersecting and fault types provide a key to understanding the hydrology of karstic area. However in study area there are good outcrops of the fracture, faults and also so many ground water discharge point. Fracture system in the region have been characterized through field survey, geological map, interpretation of aerial photo graph, remote sensing of satellite images and integration in GIS.Tectonics element such as faults, syncline and anticline axes, joints, lineaments and their analysis have provided new insights into a vast array of hydrogeology. Lineament is natural simple or composite-pattern linear or curvilinear features discernible on the Earths surface, In the geologic sense, these features my depict crustal weakness. These originate mainly from strains that arise from stress concentrations around flaws, heterogeneities and physical discontinuities, largely reflected in the form of fault, fractures, joints sets, or dykes [1]. In the last two decades structural elements have been widely practiced by [2-10]. This paper studies the geostructural and hydrological elements in the Lar region, in the central Alborz mountains,some 85 km North East of Tehran (capital of Iran),which are extracted and interpreted from geological map, aerial photo, Land sat imagery and DEM data. The propose of this research was to improve the understanding of the role of structural element in reconnaissance of karst hydrology in the Lar catchment.also establishing relationships between remote sensing data and hydro geologic setting in the area.

MATERIALS AND METHODS

Study Area: Approximately 11 percent pf the territory of Iran is covered by carbonate rocks [11]and within the study area 33 percent is occupied by exposed karstified carbonate rock, in which sinkholes, caves and karstic springs occur locally .The research was conducted within the Lar catchment located in upstream of Lar dam, southern part of Alborz Mountains and 85 km far from Tehran city, Iran. The study area, about 750 km^2, located in the coordinates of between 35, 48 to 36, 04 N and 51.32 to 52.04 E and at the elevations of 2400-5670 m above sea

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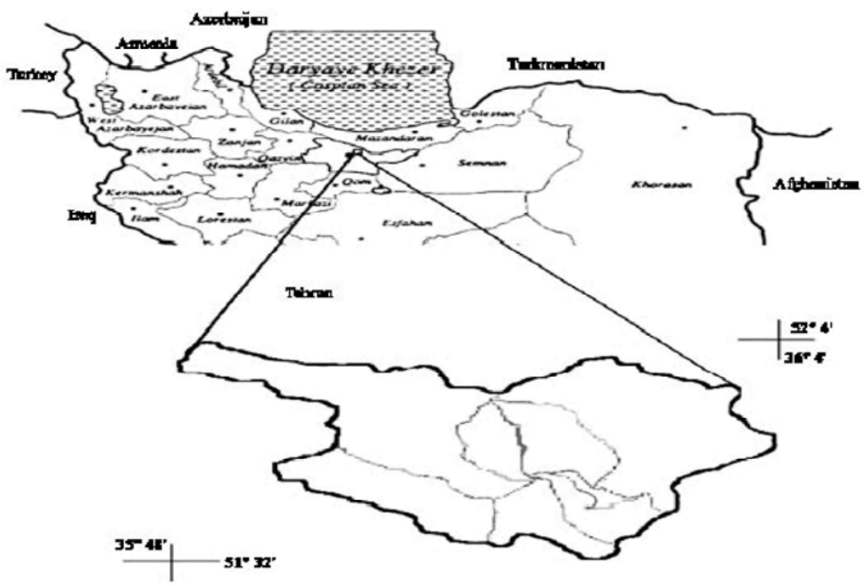

Fig. 1: Location map of the study area

level, as a part of Lar river catchments, has been shown in Fig. 1. Lar River flows from North West to south west and has 6 main tributaries. The area covers the middle sector of the Alborz Mountains. The Alborz Mountains are a continuation of the Alpine Type Mountains, which are a complex asymmetric belt of folded and faulted rocks [12]. The area is mainly underlain by limestone, volcanic beds and lake deposits. The limestone units consist of medium bedded limestone of upper Jurassic age (Lar formation) and a massive fine grained limestone of Early Cretaceous age (Tiz-koh formation) and marly limestone of Middle Jurassic (Dalichai formation). The volcanic rocks include mainly trachy- andesitses, formed by the activities of Damavand Mountain which is of Early Pleistocene age and also Tuff of Miocene age (Karaj formation). The lake deposits consist of two units informally named as lower and upper deposits [13] .This research was accomplished pusing ILWIS 3.1 (Integrated Land and Water Information System), PCI EASI/PACE 8.2 and Microsoft Excel software at Research Institute for Water scarcity and Drought in Agricultural and Natural Resources (RIWSD). Land Sat TM 2002 satellite images and 1/50000 scaled topographical maps, geological maps and black and white 1/20000 aerial photos used in this research were supplied from Geological Survey of Iran and Iran Remote Sensing center.

Method of Investigation: The extraction of the tectonic elements that have deformed the rocks is one of the important tools for determining of the direction of the most opened fractures. The most elementary approach is to make rose-diagrams of structural elements to expect to find out some relation between them and hydrological data. To aim the role of structural elements identification, in karst hydrology a karst potential map were prepared and then based on geological and hydrological and remote sensing data, different thematic layers like, tectonic element .lineament, litho logy, spring, slope and elevation class, drainage network and density and shallow ground water map were prepared and integrated in a GIS to investigate relationship between geostructural and hydrological data. To find out the role of karst systems, in sustainable base flow, a river and spring discharge monitoring survey carried out during the dry season and also daily flow analysis were down.

Karst Related Features and the Main Thematic Layers: Tectonics elements such as, faults, joints, folds and bedding pattern play an important role in the karstification and lineaments derived from remotely sensed data can be correlated with vertical or near vertical zones of fractures concentration which can act as conduits for transport and storage of ground water. With this hypothesis different thematic layer were prepared as an indication and reflection of karstification .They are as fallow;

Lithology map, Karst potential base map, Tectonic element map,Lineament map,Rose diagram,Drainage network,(Lineament, drainage network and tectonic element) density map,Shallow ground water map,Springs location map,Slope and elevation map Distribution of springs in different litlogical units,

Data Management and Processing: In this phase, first, all data were converted to digital format and then different layers, integrated in GIS. Results are shown in Tble.1. Flow component separation and recession curve analysis were carried out, fallowed by analysis and interpretation of the results.

Hydrologic Setting: The data available for study area are rainfall and time series records of stream flow discharge, Supplemented with base flow measurements made during the fieldwork. Hydrograph analyzing and interpretation of the base flow is all that is available for studying possible effects of karst. The study area is a mountainous area influenced by air masses of Mediterranean and Caspian Sea origin and climate is classifies as cold arid or cold-semi arid, The mean annual precipitation over the catchment is about 697mm calculated from the data of 10 stations, within and close to the study area. There are three hydrometric stations within the area, including Dalichai, Sefid Ab and Lar. Only stream flow data from Lar station is used for analysis, due to lack of precise data of the other stations.

Flow Duration Curve: The flow duration curve is the empirical cumulative frequency distribution function of the entire daily stream recorded at a site and describes the fraction of the time over the entire record that different daily flow levels were exceeded [14]. The flow duration curve is a useful tool for illustrating the flow characteristics of a catchment and ground water contributions [15]. In this research daily flow duration data for three years (dry, wet, normal) and whole period of study, were compared in order to determine the drying trends and ground water contribution to stream flow, Fig 8, shows interesting data. The short duration flows are clearly influenced by the precipitation, but there is not much difference in the long duration flow. This indicates strong buffering characteristic of a permeable catchment with a substantial ground water contribution.

Base Flow Index (BFI): The base flow index (BFI) is a dimensionless ratio developed by [15-17]. This index can present some information about the proportion of the runoff that originates from stored sources [15]. Fig.9,.Shows variation of BFI and annual runoff in period (1967-1976), higher runoff years experience higher and low runoff years experience lower BFI value and high value of base flow index shows that a major portion (60 % to 80%) of the stream flow of Lar river comes from the ground water.

Recession Curve Analysis: The recession curve tells in general way about the natural storages feeding the stream. Accordingly, it contains valuable information concerning storage properties and aquifer characteristics. The recession curve has traditionally been separated into the linear components of surface, unsaturated and saturated flow. The components are thought to represent different flow path, in the catchment [17-19].

Base Flow Recession Curve of Lar River: According to [20] the start of the recession period was considered to be the day when a 3-day moving average began to decrease and then different hydrograph is plotted on semi-log paper. By sliding the first point of inflection over the other, different base flow recession curve of Lar River is constructed in one graph. As is shown in Fig.10, There are three main recessions, overland flow, direct runoff, flows near the surface (inter flow), termed delayed flow here and ground water flow recession .The recession of base flow is similar from year to year but there is a considerable variation in the recession rate that can be caused by difference in climate or according to [21] it can be the result of several aquifers.

In the Lar Catchment There Are Two Conceptual Reservoirs:

- Relatively shallow system with permeable conditions causing a recession from a bout 50-60 m^3/sec to a bout 20 m^3/sec in a period of 100 to 110 days. The physical reservoir could be the thick scree slope, shallow karst, perched water table and river terraces. There is same annual variation.
- A deep system consisting of a coherent ground water body. Annual variation is minor

Lapsed Variation of the Recession Constant: The recession constant, interpreted in literature as a representative of the residence time or the turnover time of the ground water [22], Fig.11 shows variation of the recession constant in the study catchments for 10 years. Physically based variation in the recession rate is caused in climate during the time of recession, but also determined by the conditions prevailing prior to the start of the recession [18]. Recession constant in this study period shows variability. Reducing recession constant in 1973 can be interpreted as the result of reducing rain fall, for the period of 1968-72 there is decreasing trend in rain fall but there is no large fluctuation in recession constant, this can be the result of ground water contribution from the karst system, to stream flow.

River and Springs Discharge Monitoring: A river and spring discharge monitoring survey carried out during the dry season shows high contribution of the big springs to the stream flow. Of 24 springs measured in the study area, 18 had a finite flow during the summer of 2002.The 9 largest springs account for approximately 76% of the spring discharge.

The 6 large springs that directly enter Lar River account for approximately 68% of the total river discharge, during the dry season, this high value shows high ground water contribution to stream flow. Different discharge measurement along the river, were carried out and after delineating catchments boundary and calculating area covered by different units, is plotted, Relationship between, non-karstic permeable and impermeable area, with specific discharge shows increasing trend, whilst, limestone area and alluvium shows some scatter, this is not in line of expectation and it could be the result of existence of different, karstic aquifers and ground water emergence in the alluvium.

RESULTS AND DISCUSSION

One of the most useful methods in karst water resource evaluation is comprehensive analysis of karst related features (lineament, fault, joint) from aerial photo, satellite image, geological map, fieldwork data and also hydrological data processing. In karst potential map (Fig.2) generated based on previous described criteria a continuous body of karst units bounded by non-karstic terrains was distinguished, also there is a small discontinuity in north west, north and south of the study area. From the dominant trends of lineament extracted from satellite image and the tectonics elements map (Fig.2, Fig.3) and the location of discontinuity, it is likely that underground passageways and exchange of ground water occurs between adjacent catchments and sub catchments within the Lar catchments. This is also confirmed by presence of large and active sinkholes in the Lar catchment and known underground water losses to the reservoir. A rose diagram generated for lineaments, extracted from satellite image (Fig.3.), suggest that the dominant lineaments orientation is between 140-170 N-W degrees that can be related to the main structural direction .The second lineament trend lies between 140-110 N-W shows cross folding or shear zones. The third class of lineaments is orthogonal to the first directions and is consistent with the counterclockwise rotation of compressive stress. This study has led to the valuable in sights regarding the properties of structural elements and lineaments and their hydrological significance. From the relationship between Frequency of springs and distance away from lineament (Table.1.1.) signifies the role of lineaments in conveying water. Relationship between Frequency of springs and distance away from main tectonic elements (Table.1.1) shows a tendency for springs to occur at short distance from tectonic elements, it can be concluded that tectonics elements are conduits of water. By comparing the Frequency of springs with the distances away from main tectonic elements (Table.1.1)

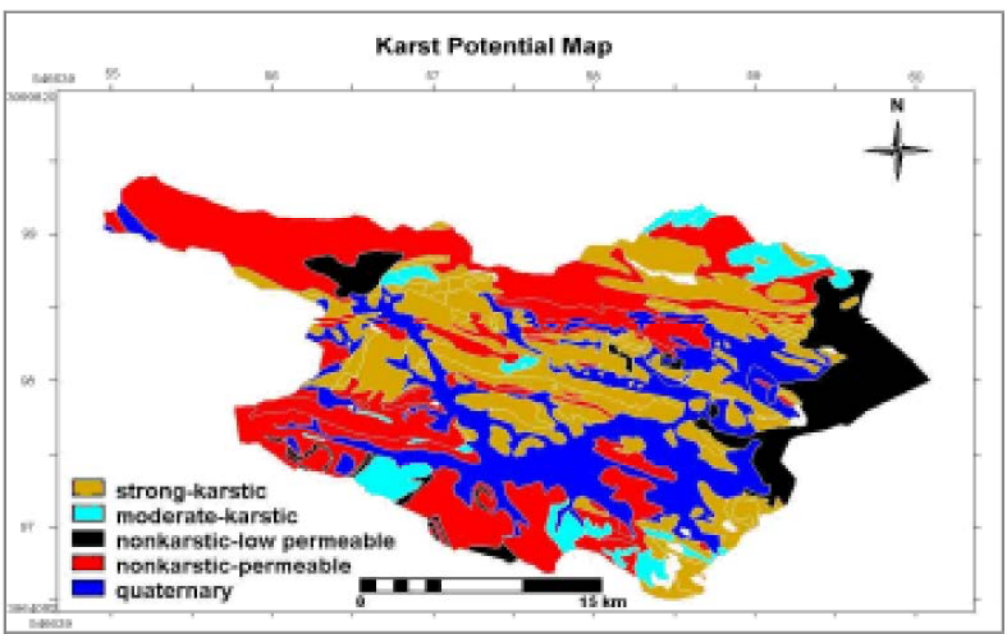

Fig. 2: Karst potential base map of the study area

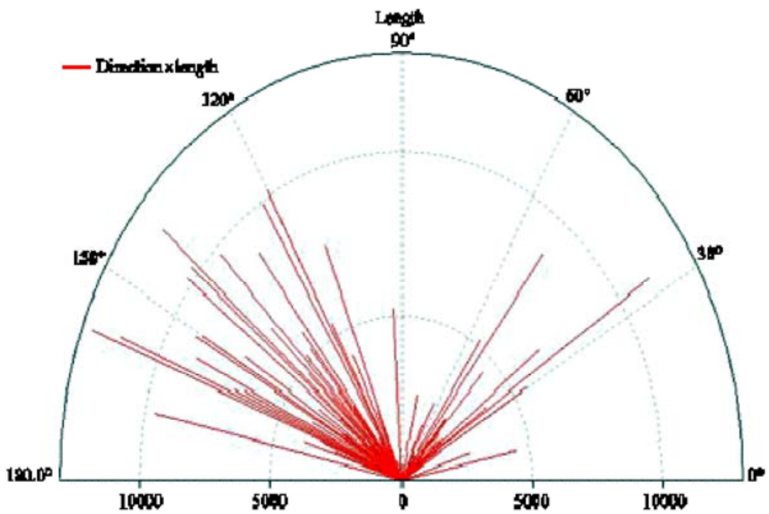

Fig. 3: Rose diagram for the lineaments showing major trends of lineaments occurring in the study area

Table 1: Relationship Between Geostructural and Geomorphologic Elements with Frequency of Springs

The parameter of investigated	Regressions
Relationship between slope class and frequency of springs	R2 = 0.9449 y = 42.714e-0.3238x
Relationship between elevation class and frequency of springs	y = -6.2732Ln(x) + 21.926 R2 = 0.7204
Relation ship between frequency of springs and distance from tectonics elements	y = 0.8848x + 14.867 R2 = 0.8971
Relationship between frequency of springs and distance from stream network	y = -6.9x + 40.7 R2 = 0.8532
Relationship between frequency of springs and distances away from lineaments.	y = -1.9083x + 19.208 R2 = 0.9776
Relationship between tectonic elements length and frequency of springs in sub catchments of study area	y = 0.8245x + 13.026 R2 = 0.6213
Relationship between tectonic elements length and drainage length	y = 0.2462x + 23.89 R2 = 0.8758
Relationship between drainage length and frequency of springs	y = 0.2477x + 25.931 R2 = 0.8111
Relationship between ratio of tectonic elements density over drainage density and frequency of springs	y = 0.0861x + 0.3643 R2 = 0.8801
Relationship between internal relief and discharge of springs	y = 0.0354x + 334.22 R2 = 0.0079
Relationship between discharge of springs and catchments size	y = 23.895x + 103.94 R2 = 0.4541
Relationship between EC and discharge of springs in study area	y = 0.2053x + 90.428 R2 = 0.0265

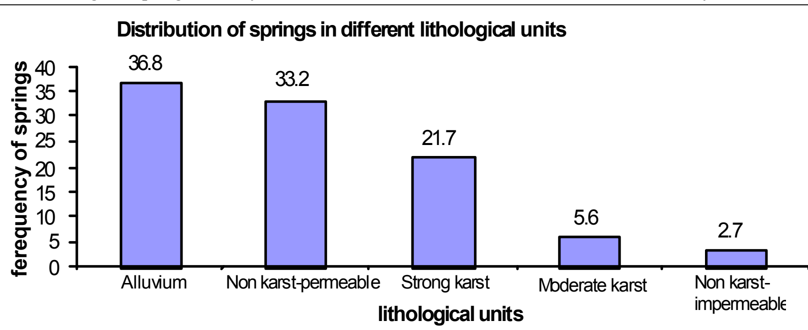

Fig.4: Distribution of springs in different litho logical units

and lineaments only a minor difference was found and this supports the significance of the lineament interpretation. From the good correlation between Frequency of springs and tectonic elements length (Table.1.1) and also the concentration of springs close to the lineament and tectonic elements, It was concluded that fractures, indicate zone of enhanced porosity and conductivity, thus can have a positive influence on the ground water occurrence and they act as transmission routes in the limestone bodies. From suitable relationship between the tectonic elements length and number of springs, (Table.1.1) the relationship between drainage length and number of springs and the relationship between tectonic elements and drainage length, it is concluded that number of springs and drainage length are a function of tectonic elements. Thus tectonic elements

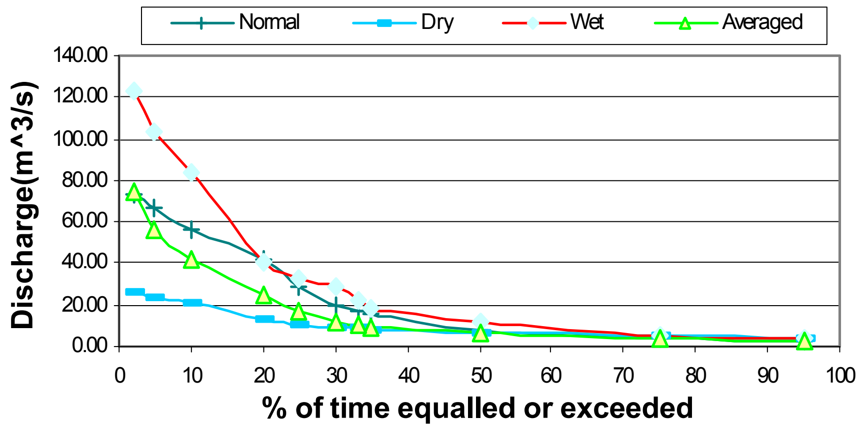

Fig. 5: Flow duration curve of the Lar River

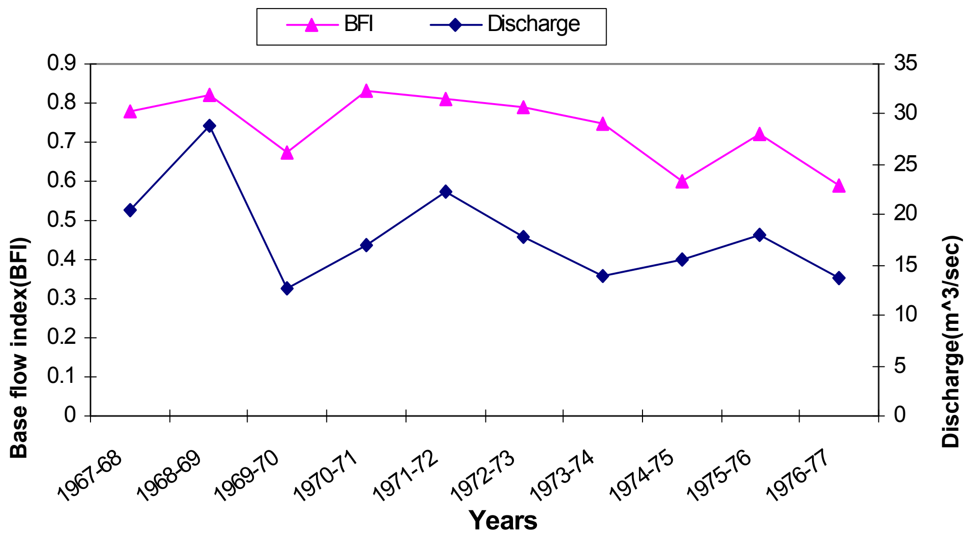

Fig. 6: Variation of base flow index and runoff in study catchment

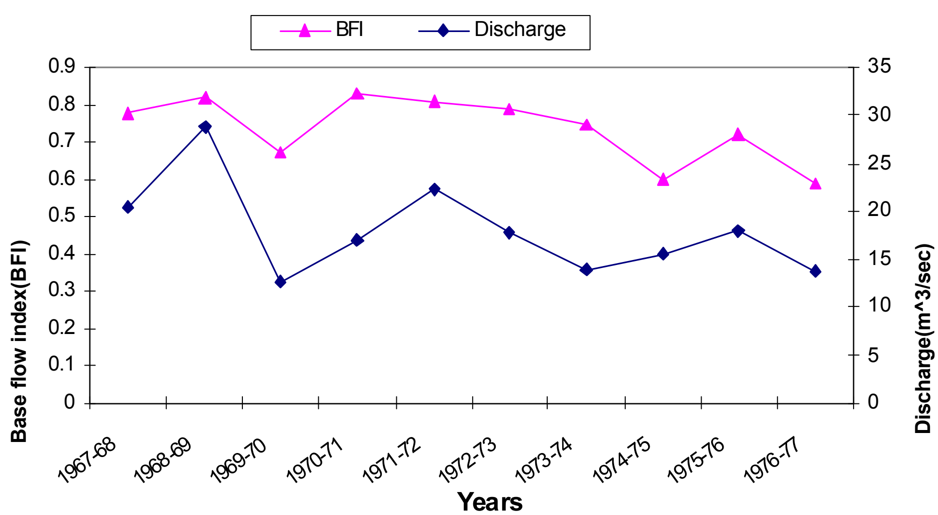

Fig. 7: Annual recession curve for 10 consecutive years for Lar River (1967-

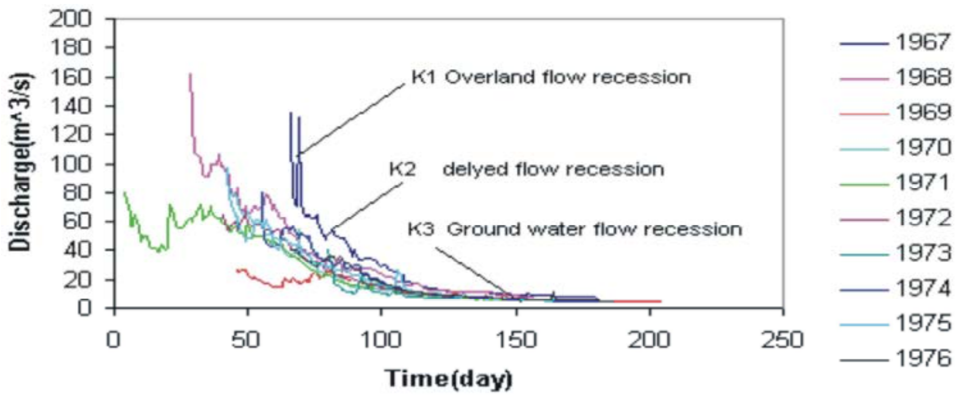

Fig. 8: Variation of recession constant for 10 consecutive years

influence the hydrogeology of the study area. From the association of the ratio of tectonic elements over drainage density and number of springs (Table.1.1) it was found that a high value of this ratio can show ground water occurrence in study area, concentration of springs is found in the lower slope class. Springs occurring on steep slopes indicate local geolgical control. The same is true for the relationship between elevation class and percentage of springs. Resulting from crossing and distance operation between stream network and springs shows a tendency for springs to occur at short distance from stream network. This is expected because of the way ground water flows in ground water flow systems. Distribution of springs in different lithological units (Fig.4,) shows a decreasing trend from strongkarst to moderate karst and non karst impermeable units that were in line of expectation, fairly large percentage of springs in non karst but permeable units can be the result of fracture flow. The relationship between number of springs in karstic area and distance away from limestone contact (Table.1.1) shows a tendency for springs to occur at short distance from limestone contact, this can bet he result of ground water escaping from the karstic area through the shear zone near contacts of competent and incompetent rocks. From overlaying stream network on the shallow ground water layer derived from NDVI, it can be concluded that existence of vegetation that is not in the valleys, indicates, wet soils or shallow groundwater. Such area could be recharge area. The poor relationship between quality and quantity of springs with each other and with catchments characteristics (Table.1.1) were not in line of expectation, it is due to geologic controls. From the relationship between rainfall-runoff and delay in response to rainfall, high permeability of the catchment can be concluded. Recession curve analysis shows that there is an intermediate and a deep reservoir; the latter correspond to a coherent ground water body in a considerable part of the catchment's. Recession constants, base flow indexes and flow durations all indicate an important contribution of ground water from a coherent ground water body to the runoff. It is likely that these are carry - over effects from one water year to another, because annual rainfall variations have little effect.

CONCLUSION

It can be concluded that in order to reconnaissance of karst hydrology combination of hydrological and geostructural elements using capability of remote sensing and geographic information system can be recommended, also analyzing spatial distribution of ground water discharge points can be suggested. This study has led to the valuable in sights regarding the properties of structural elements and their hydrological significance.

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